The Araucaria Project. First Cepheid Distance to the Sculptor Group Galaxy NGC 7793 from Variables discovered in a Wide-Field Imaging Survey [1]

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ABSTRACT

We have detected, for the first time, Cepheid variables in the Sculptor Group spiral galaxy NGC 7793. From wide-field images obtained in the optical V and I bands on 56 nights in 2003-2005, we have discovered 17 long-period (24-62 days) Cepheids whose periods and mean magnitudes define tight period-luminosity relations. We use the (V-I) Wesenheit index to determine a reddening-free true distance modulus to NGC 7793 of 27.68 ± 0.05 mag (internal error) ± 0.08 mag (systematic error). The comparison of the reddened distance moduli in V and I with the one derived from the Wesenheit magnitude indicates that the Cepheids in NGC 7793 are affected by an average total reddening of E(B-V)=0.08 mag, 0.06 of which is produced inside the host galaxy.

As in the earlier Cepheid studies of the Araucaria Project, the reported distance is tied to an assumed LMC distance modulus of 18.50. The quoted systematic uncertainty takes into account effects like blending and possible inhomogeneous filling of the Cepheid instability strip on the derived distance. The reported distance value does not depend on the (unknown) metallicity of the Cepheids according to recent theoretical and empirical results. Our Cepheid distance is shorter, but within the errors consistent with the distance to NGC 7793 determined earlier with the TRGB and Tully-Fisher methods.

The NGC 7793 distance of 3.4 Mpc is almost identical to the one our project had found from Cepheid variables for NGC 247, another spiral member of the Sculptor Group located close to NGC 7793 on the sky. Two other conspicuous spiral galaxies in the Sculptor Group, NGC 55 and NGC 300, are much nearer (1.9 Mpc), confirming the picture of a very elongated structure of the Sculptor Group in the line of sight put forward by Jerjen et al. and others.

Subject headings: distance scale - galaxies: distances and redshifts - galaxies: individual: NGC 7793 - galaxies: stellar content - stars: Cepheids

1. Introduction

In our ongoing Araucaria Project (Gieren et al. 2005a), we are engaged in an accurate determination of the environmental dependences of several of the most important stellar methods of distance determination, with the aim to improve the currently weakest link of the calibration of the extragalactic distance scale, the determination of the absolute distances to galaxies in the near field. These form the fundament for the calibration of secondary methods of distance determination reaching out into the unperturbed Hubble flow, where the Hubble constant can be reliably measured from distance and velocity data. One of the most important stellar methods to measure the distances to nearby galaxies is the period-luminosity (PL) relation obeyed by Cepheid variables. This is particularly true when the PL relation is used at near- or mid-infrared wavelengths (e.g. Persson et al. 2004, Freedman et al. 2008) where the effect of reddening on the measured distances becomes small or even negligible. In the lack of infrared photometry, an excellent alternative to derive very accurate Cepheid distances is to use the (V-I) Wesenheit function W_I. Recent evidence from our own project (Pietrzynski and Gieren 2006) and other work (Bono et al. 2010) shows that not only the effect of reddening on the derived distances is minimized, but also the effect of the (many times unknown) metallicity of the Cepheid populations in the target galaxies on the derived distances is very small. In previous papers, we have reported on the discoveries of abundant Cepheid populations in a number of irregular galaxies in the Local Group (Pietrzynski et al. 2004, 2006a, 2007), and in several spiral galaxies members of the Sculptor Group (Pietrzynski et al. 2002, 2006b; Garcia et al. 2008). These galaxies span a broad range of metallicities which is useful not only to study the dependence of the Cepheid PL relation on this parameter, but also of other tools for distance determination studied in our project, like the Flux-Weighted Gravity-Luminosity Relation obeyed by blue supergiant stars (Kudritzki et al. 2008, Urbaneja et al. 2008).

In this paper, we report on the discovery of a population of Cepheids in another target galaxy in the Sculptor Group included in our project, NGC 7793. NGC 7793 is a relatively tightly wound spiral of type Sd (Sandage & Bedke 1988), similar in appearance to NGC 300 in the Sculptor Group. Unlike NGC 300 however, little work has been done in the past to determine the distance to NGC 7793. Only two distance indicators have been applied on NGC 7793: the I-band TRGB method, and the Tully-Fisher (TF) method. While the TF method has yielded a distance modulus of 28.06 $\pm$ 0.35 mag (Tully et al. 2009), application of the TRGB technique has resulted in a distances of 27.96 $\pm$ 0.24 mag (Karachentsev et al. 2003), and more recently of 27.79 $\pm$ 0.08 mag (Jacobs et al. 2009). The Jacobs et al. determination was made from HST data obtained in an outer field of NGC 7793 which explains its higher accuracy, as compared to the result of Karachentsev et al. which was measured from HST data obtained for a field located much closer to the center of the galaxy, where crowding and internal extinction may have complicated the TRGB measurement. Given that NGC 7793 contains a considerable number of blue massive stars indicating recent star formation, we expected to find a sizeable population of classical Cepheids in it which would provide an independent and accurate check on the previous distance determinations. Indeed, our survey has led to the detection of 17 long-period Cepheids. In this paper, we are using these Cepheids to determine the first Cepheid-based distance to NGC 7793, which adds a valuable target to the existing Araucaria Project database with a distance from this indicator.

Our paper is organized as follows. In section 2, we describe our observations, data reductions and calibrations. In section 3, we present the catalog of photometric properties of the Cepheid variables discovered in our survey in NGC 7793. In section 4, we construct the period-luminosity relations in V, I and the reddening-free (V-I) Wesenheit index and determine the distance and internal reddening of NGC 7793 from these data. In section 5, we discuss our result and assess its accuracy. The main conclusions are presented in section 6.

2. Observations, Reductions and Calibrations

All the data presented in this paper were collected with the Warsaw 1.3-m telescope at Las Campanas Observatory. The telescope was equipped with a mosaic 8k $\times$ 8k detector, with a field of view of about 35 $\times$ 35 arcmin and a scale of about 0.25 arcsec/pix. For more instrumental details on this camera, the reader is referred to the OGLE website: *http://ogle.astrouw.edu.pl*. V and I band images of NGC 7793 were secured on 56 different nights. The exposure time was set to 900 seconds in both filters. The observations were obtained between July 2003 and December 2005.

Preliminary reductions (i.e. debiasing and flatfielding) were done with the IRAF[2] package. Then, the PSF photometry was obtained for all stars in the same manner as in Pietrzyński, Gieren and Udalski (2002). Independently, the data were reduced with the OGLE III pipeline based on the image subtraction technique (Udalski 2003; Woźniak 2000).

In order to calibrate our photometry onto the standard system our target was monitored during two (non-contiguous) photometric nights together with some 25 standards from the Landolt fields spanning a wide range of colors (-0.14 < V-I < 1.43), and observed at widely different airmasses. Since in principle the transformation equations for each of the eight chips may have different color coefficients and zero points, the selected sample of standard stars was observed on each of the individuial chips, and transformation coefficients were derived independently for each chip, on each night. Comparison of the photometry obtained on the different nights revealed that the internal accuracy of the zero points in both V and I bands is better than 0.03 mag. In order to demonstrate this, we show in Table 3 the zero point and color term values for the eight chips for the two calibrating photometric nights. Within the errors there are no color term variations from night to night. Slight zero point differences for individual chips from 0.02-0.04 mag are present. We note here this (OGLE) telescope and setup has been used now for 14 years for photometric surveys and is certainly one of the most stable photometric systems in the world. Never any significant color drift has been observed.

To correct the variation of the zero points in V and I over the mosaic, the "correction maps" established by Pietrzynski et al. (2004) were used. These maps were already applied to correct photometry obtained in the field of NGC 6822 (Pietrzynski et al. 2004) and NGC 3109 (Pietrzynski et al. 2006a). Comparison with other studies revealed that these maps allow to correct the zero point variations down to a level of 0.02-0.03 mag.

Unfortunately, we were unable to find any modern photometry of of NGC 7793 in the literature which could be used to check the accuracy of the zero point of our photometry. However, taking into account that the present photometric calibration was performed in an identical way as for the other nearby galaxies surveyed for Cepheids in the Araucaria project, and that in all cases a comparison of our photometry with the corresponding results published in the literature had shown very good agreement, we are very confident that our photometric data of NGC 7793 are also accurate to 0.03 mag in both V and I, and that a possible variation of the photometric zero points in both filters over the mosaic fields is

[2]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the NSF.

indeed smaller than 0.03 mag.

3. Cepheid Catalog

All stars detected in NGC 7793 were searched for photometric variations with periods between 0.2 and 200 days, using the analysis-of-variance algorithm (Schwarzenberg-Czerny 1989). In order to distinguish Cepheids from other types of variables, we used the same criteria given in our initial paper reporting on the discovery of Cepheids in NGC 300 (Pietrzynski et al. 2002). The light curves of all Cepheid candidates were approximated by a 4th order Fourier series. We then rejected objects with amplitudes of their V light curves smaller than 0.4 mag, which is the approximate lower limit of V amplitudes for classical Cepheids. This procedure also helped us in screening our Cepheid sample from the inclusion of strongly blended variables. For the variables passing our selection criteria, the mean V and I magnitudes were derived by integrating their light curves which had been previously converted onto an intensity scale, and converting the results back to the magnitude scale.

Our final catalog contains 17 classical Cepheids with periods between 24 and 62 days. Fourteen of these variables have light curves in both V and I filters. Three additional Cepheids have only V-band light curves. Two of them are the faintest Cepheids in our sample and were too faint to measure their I-band light curves from our images. The third Cepheid with V-band data only is the longest-period variable we discovered (91 days), but unfortunately it was located in a gap between the chips of our mosaic camera in the I images. There are certainly many more Cepheids in NGC 7793 with shorter pulsation periods which we were not able to discover because of the small size of the telescope we had at our disposal for this survey; yet, the sample of long-period and relatively bright Cepheids detected in our survey is completely adequate for our purpose to derive an accurate distance to NGC 7793, as we will show in the next section.

The journal of the individual V and I observations of the Cepheids is presented in Table 1. Table 2 summarizes the photometric properties of the newly discovered Cepheids in NGC 7793: their periods, and their intensity mean magnitudes in V, I and in the (V-I) Wesenheit band (defined as W_I = I - 1.55($< V > - < I >$); see Udalski et al. 1999). The periods of the Cepheids are typically accurate to $10^{-3} * P$. Table 2 also reports precise equatorial coordinates for all the variables. In Figure 1, we show the locations of the Cepheids discovered in our survey in their host galaxy NGC 7793.

In Figure 2, we show the light curves of the complete sample of NGC 7793 Cepheids which illustrate the good quality and phase coverage of our data. Figure 3 shows the locations of the Cepheids on the V, V-I color-magnitude diagram for NGC 7793 constructed from our data. It is seen that all Cepheids lie in the expected region of the CMD which delineates the Cepheid instability strip, presenting supporting evidence that all variables in Table 2 were classified correctly as classical Cepheids. Figure 3 does of course not include the 3 Cepheids which have no I-band light curves, but the shapes and amplitudes of their V light curves, periods and mean V brightnesses leave no doubt that they are classical Cepheids too.

4. PL relations and distance determination

In Figures 4-6, we show the PL relations in the V, I and W_I bands resulting from the data in Table 2. The V-band PL diagram contains the 3 variables which have V data only; these 3 variables are, however, not included in the distance determination. Fits to a straight line to our data yield the following slopes for the PL relations: -3.24 $\pm$ 0.25, -3.17 $\pm$ 0.18 and -3.07 $\pm$ 0.30 in V, I and $\mathrm{W_I}$, respectively. The uncertainties on the slopes are rather large due to the relatively small number of Cepheids in the PL diagrams. The slope values however are consistent, at a level of 2 σ, with the corresponding OGLE slopes of -2.775, -2.977 and -3.300 for the LMC (Udalski 2000). We therefore use, as in our previous papers, the extremely well defined OGLE PL relation slopes determined for the LMC to fit our observed PL diagrams in NGC 7793. Remarks on the validity of this approach will be given in the next section. Adopting the LMC slopes in fitting our data leads to the following equations:

$$\mathrm{V} = -2.775 \log \mathrm{P} + (26.48 \pm 0.04)$$

$$\mathrm{I} = -2.977 \log \mathrm{P} + (25.91 \pm 0.03)$$

$$\mathrm{W_I} = -3.300 \log \mathrm{P} + (25.04 \pm 0.04)$$

The uncertainties on the zero points have been calculated from the least-squares fitting. Adopting 18.50 mag as the true distance modulus to the LMC, as we did in our previous papers in this series, a value of E(B-V) = 0.018 mag as the Galactic foreground reddening towards NGC 7793 (Schlegel et al. 1998) and the reddening law given by the same authors ($\mathrm{A_V}$ = 3.24 E(B-V), $\mathrm{A_I}$ = 1.96 E(B-V)) we derive the following distance moduli for NGC 7793 in the three different bands:

$(m - M)_0$ (W_I) = 27.68 ± 0.05 mag

$(m - M)_0$ (I) = 27.78 ± 0.03 mag

$(m - M)_0$ (V) = 27.86 ± 0.04 mag

Again, the uncertainties on these values are derived from least-squares fitting. The distance moduli values indicate, not surprisingly, that there is additional reddening intrinsic to NGC 7793 affecting the Cepheids. A value of E(B-V)=0.06 mag for the average intrinsic reddening, bringing the total mean reddening affecting the NGC 7793 in our sample to 0.08 mag, produces excellent agreement, at the 0.02 mag level, between the distance moduli for NGC 7793 derived from the PL relations in V, I and W_I. We adopt, as our best Cepheid distance from the present optical study, the value of 27.68 mag derived from the Wesenheit index. In the next section, we discuss the various systematic uncertainties which may affect this value, and estimate the total uncertainty on this first Cepheid distance determination to NGC 7793.

5. Discussion

The current distance measurement of NGC 7793 is the first one based on Cepheid variables, and subject to the different sources of systematic uncertainty inherent to this particular method. The first potential problem is with reddening because Cepheids, as relatively young stars, tend to be located in dusty regions in their host galaxies. While infrared photometry is the best way to minimize or even completely avoid this problem, our past work, and that of others, most notably the OGLE Project (Udalski et al. 1999; Soszynski et al. 2008), has shown that in Cepheid distance work reddening can be very effectively dealt with by using the (V-I) Wesenheit magnitude, as we have done in this paper. In all our previous papers in this series, the true distance moduli based on the Cepheid Wesenheit magnitudes agreed within the (small) uncertainties of the determinations with the distances coming from the near-infrared follow-up studies (e.g. Gieren et al. 2005b, Gieren et al. 2008, 2009). While our intention is to check on the current distance determination to NGC 7793 using near-infrared data in the near future, we believe that the Cepheid distance presented in this paper is basically free of any significant error due to inadequate absorption corrections. In any case, NGC 7793 is a favorable target in this sense given that the Galactic foreground reddening towards the galaxy is practically negligible, and from our results in the previous section we know that the average reddening produced inside the galaxy on the Cepheids is quite small too.

At a distance of 3.4 Mpc blending of Cepheids with nearby stars not resolved in the photometry is certainly a significant problem. For one of our target galaxies, NGC 300, we have made a stringent test on the effect of blending on a Cepheid-based distance, comparing the results from ground-based photometry in V and I to HST-based photometry of the same Cepheids (Bresolin et al. 2005). The result was that blending affects the ground-based distance result by less than 2%, in this particular case. NGC 7793 has a very similar inclination with respect to the line-of-sight, with an orientation close to face-on, as NGC 300; however, since its distance is by a factor of 1.8 larger, the effect of blending is expected to be more serious than in the case of NGC 300. Scaling linearly with the distance, we expect that 3% is a reasonable upper limit to the systematics from this source. We tested this hypothesis by degrading the resolution of the ground-based images of NGC 300 to the one expected at the distance of NGC 7793, and redoing the photometry of the Cepheids observed with HST. The result is that indeed the effect of blending is somewhat larger now, but less than 3%, in agreement with our simple expectation from rescaling the error according to the larger distance of NGC 7793. It should also be noted in this context that the amplitudes of the light curves in Figure 1 are generally about as large as expected for the periods of the Cepheids (although there is no strict period-amplitude relation for classical Cepheids), which probably implies that none of these Cepheids is strongly blended, which depending on the color of a bright nearby star contaminating the Cepheid photometry would tend to reduce the light curve amplitude in V (blue companion) or I (red companion) (Gieren 1982). Regarding the effect of blending, it should be recalled that it acts to make Cepheids brighter, and thus to underestimate the distance to their host galaxy.

Since the PL relation method is a statistical one and requires that the PL plane is populated by a sufficient number of Cepheid variables to minimize problems due to an incomplete, selective filling of the instability strip, the relatively small number of 14 Cepheids in our present study is a potential reason of concern. However, both the filling of the instability strip on the CMD in Figure 2 by the variables in our catalog, as well as the non-systematic scatter of the residuals around the fitting lines in Figures 3-5 suggest that the Cepheid variables in this study do populate the instability strip quite homogeneously, with no clear preference towards either the blue nor the red edge of the strip. Also, the current distance determination should not be affected at a significant level by a Malmquist bias which could originate when the faintest Cepheids in the sample were very close to the cutoff magnitude of the photometry. Figure 2 suggests that the faintest of the 14 Cepheids used in the distance determination is still about a full magnitude brighter than the faint star limit of our photometry. The effect of a Malmquist bias is to make the slope of the observed PL relation too shallow because at the short-period (faint) end of the sample only Cepheids are detected which are very bright, for the value of their period. Another argument giving us confidence that our distance determination is not significantly affected by a Malmquist bias, is the fact that the slopes of the free linear fits to a line in the V- and I-band PL planes are both steeper than the assumed true (LMC) slopes on these diagrams, which is the opposite to what would be expected if a significant Malmquist bias was indeed affecting the data in Figures 3 and 4.

A problem which has been very intensively discussed in the recent literature is the effect of metallicity on the Cepheid PL relation, both in optical and near-infrared photometric bands. A very nice and complete summary of the work on the metallicity effect on the PL relation, and corresponding conclusions both from observations and theoretical modelling of Cepheids, has been recently presented by Bono et al. (2010). In particular, these authors find that the (V-I) Wesenheit PL relation used in this study to determine the distance to NGC 7793 has a slope which *independently of metallicity* agrees always very well with the LMC slope we have been using in our analysis. This empirical result is backed up by the predictions of their pulsation models for fundamental mode Cepheids and thus appears to be a very solid conclusion. In addition, Bono et al. conclude from their analysis that the *zero point* of the absolute (V-I) Wesenheit PL relation does not depend on metallicity either, over a broad range of metallicities, a conclusion reached from the available data and again supported by their theoretical models. We note here that from the (preliminary) dataset from the Araucaria Project alone available to us in 2006, we had reached the same conclusion (Pietrzynski & Gieren 2006). As a conclusion, any effect of the (currently unknown) mean metallicity of the Cepheids in our NGC 7793 sample on the distance we have derived in this paper, should be negligible.

An issue of concern is the fact that the observed dispersion in the W_I Wesenheit PL relation in Figure 6 is slightly larger than the one shown by the I-band PL relation in Figure 5. We believe that the main reason for this is the photometric contamination of some of the Cepheid mean magnitudes in Table 2 by nearby, unresolved companion stars (discussed above). While this effect indeed tends to increase the scatter in Figure 6, it should not change the distance derived from this diagram within the uncertainties we determined in our analysis in section 4 of this paper. An alternative explanation would be the validity of a non-standard reddening law in NGC 7793, the coefficient 1.55 not being appropriate in the definition of the Wesenheit magnitude to correct for reddening. We regard this as rather unlikely however, in the light of our earlier findings in NGC 300 (Gieren et al. 2005b), NGC 55 (Gieren et al. 2008) and NGC 247 (Gieren et al. 2009) where from combined optical and near-infrared photometry of the Cepheids we found solid evidence that the standard reddening law holds in these galaxies.

From the previous discussion, we identify as the dominant systematic uncertainty in the present study on the derived distance the effect of unresolved bright nearby stars on the Cepheid photometry, or blending. The systematic uncertainty on the photometric zero points in our study are less important (less than 2% on the distance modulus). We estimate the total systematic uncertainty of our distance to be 4%, with a likely tendency to act in the direction to increase the reported distance to NGC 7793. This would bring the Cepheid distance closer to the TRGB-based distance of Jacobs et al. (2009), which are clearly consistent within their respective uncertainties.

We recall that the current distance measurement of NGC 7793 *assumes* an LMC distance of 18.50 mag, in agreement with our earlier work in the Araucaria Project. While any possible future change in the adopted value of the LMC distance will obviously affect the absolute Cepheid distances of our different target galaxies reported in the Araucaria project, it will not affect the *relative* distances between the target galaxies of our project.

6. Conclusions

We have carried out a first systematic wide-field search for Cepheid variables in the Sculptor Group spiral NGC 7793 and have discovered 17 long-period classical Cepheids. We provide the periods of these objects and their mean intensity magnitudes in the optical V and I bands, as well as their accurate positions. From a subsample of 14 Cepheids having both V- and I-band light curves, we have determined the period-luminosity relations in these bands, as well as in the reddening-independent (V-I) Wesenheit band. The distance moduli derived from these PL relations demonstrate that apart from the very small foreground reddening, there is additional reddening of magnitude E(B-V)=0.06 mag produced in NGC 7793 itself and affecting its Cepheids. Our best adopted value for the distance modulus of NGC 7793 is 27.68 $\pm$ 0.05 mag (intrinsic) $\pm$ 0.08 mag (systematic). The dominant source of systematic uncertainty is the effect unresolved nearby bright stars might have on the photometric magnitudes of some of the Cepheids, which would act towards a (small) underestimation of the true distance of the galaxy. According to recent studies, our way to determine the distance to NGC 7793 using the period - (V-I) Wesenheit magnitude diagram should be independent of the metallicities of the Cepheids in our sample.

The Cepheid distance agrees very well with the recent distance determination of NGC 7793 of Jacobs et al. (2009) who used HST photometry and the I-band TRGB method. This increases our confidence that the distance to NGC 7793 is now reliably measured with a total uncertainty not exceeding 5%. Nevertheless, we intend to obtain near-infrared single-phase photometry for our Cepheid sample with the ESO VLT to determine accurate mean magnitudes in the J and K bands (see Soszynski et al. 2005) and use our multiwavelength approach (Gieren et al. 2005b) to improve the accuracy of our present distance determination from optical photometry of the Cepheids.

The present study confirms the elongated structure of the Sculptor Group in the line-of-sight first suspected by de Vaucouleurs (1959), and later substantiated by Jerjen et al. (1998), with NGC 55 and NGC 300 at the near end with near-identical distances of 1.9 Mpc, and NGC 247 and NGC 7793 at the far end at about 3.5 Mpc. From the Cepheid work in the Araucaria Project, the distances to these four galaxies are now all determined to 5% or better.

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Table 1. Individual V and I Observations

object	filter	HJD-2450000	mag	σ_{mag}
cep001	V	2851.81845	20.744	0.040
cep001	V	2853.88401	20.762	0.034
cep001	V	3260.81098	21.247	0.066
cep001	V	3263.80269	21.113	0.048
cep001	V	3267.79044	21.168	0.050
cep001	V	3270.82209	21.207	0.065
cep001	V	3286.68579	20.913	0.051
cep001	V	3289.69621	20.913	0.049
cep001	V	3295.66265	20.804	0.038
cep001	V	3297.65958	20.683	0.033
cep001	V	3299.68023	20.733	0.059
cep001	V	3305.61427	20.666	0.086
cep001	V	3311.63347	20.868	0.043
cep001	V	3314.66526	20.859	0.052
cep001	V	3324.66691	21.055	0.058
cep001	V	3327.65426	21.099	0.078
cep001	V	3328.53947	20.924	0.076
cep001	V	3339.53311	21.110	0.083
cep001	V	3354.55446	21.253	0.066
cep001	V	3615.70979	20.985	0.045

Note. — The complete version of this table is in the electronic edition of the Journal. The printed edition contains only the the first 20 measurements in V band for the Cepheid variable cep001.

Table 2. Cepheids in NGC 7793

ID	RA (J2000)	DEC (J2000)	P [days]	T_0 - 2,450,000	$< V >$ [mag]	$< I >$ [mag]	$< W_{\rm I} >$ [mag]
cep001	23:57:56.89	-32:34:16.1	91.5667	3639.6604	20.992	—	—
cep002	23:58:03.73	-32:36:01.1	62.1195	3654.5911	21.484	20.469	18.896
cep003	23:58:01.63	-32:33:47.8	57.6004	3615.7098	21.413	20.676	19.534
cep004	23:57:35.02	-32:35:36.1	54.7885	2574.6127	21.458	20.679	19.472
cep005	23:57:57.03	-32:36:37.2	54.0103	3615.7098	21.448	20.606	19.301
cep006	23:57:58.79	-32:36:23.3	48.0077	3267.7904	21.748	20.844	19.443
cep007	23:58:08.96	-32:36:12.3	47.7829	2497.9038	22.024	21.066	19.581
cep008	23:57:54.66	-32:35:44.1	39.7409	2560.6109	22.150	21.269	19.903
cep009	23:57:48.31	-32:34:21.3	36.4671	2499.8403	22.230	21.260	19.757
cep010	23:58:06.10	-32:34:20.3	31.2549	3299.6802	22.526	21.514	19.945
cep011	23:58:01.40	-32:36:23.8	28.0112	3260.8110	22.437	21.631	20.382
cep012	23:58:11.50	-32:36:35.1	27.6007	3684.5384	22.433	21.527	20.123
cep013	23:57:47.65	-32:38:00.4	26.3644	2845.6831	22.517	21.597	20.171
cep014	23:58:00.35	-32:39:19.6	26.2164	3626.6284	22.757	21.788	20.286
cep015	23:57:47.02	-32:37:14.4	26.0831	2497.8846	22.550	21.785	20.599
cep016	23:58:09.23	-32:33:41.1	25.4582	2641.5723	22.758	—	—
cep017	23:57:28.61	-32:34:18.3	24.3677	3281.7234	22.682	—	—

Table 3. The color terms (α) and zero points (β) for chips 1-8 for the two calibrating photometric nights

chip	α_{N1}	β_{N1}	α_{N2}	β_{N2}
1	-0.025	-2.207	-0.027	-2.239
2	-0.018	-2.193	-0.014	-2.201
3	-0.020	-2.204	-0.024	-2.233
4	-0.020	-2.195	-0.013	-2.210
5	-0.017	-2.123	-0.029	-2.159
6	-0.029	-2.173	-0.019	-2.223
7	-0.010	-2.179	-0.022	-2.204
8	-0.024	-2.197	-0.022	-2.137

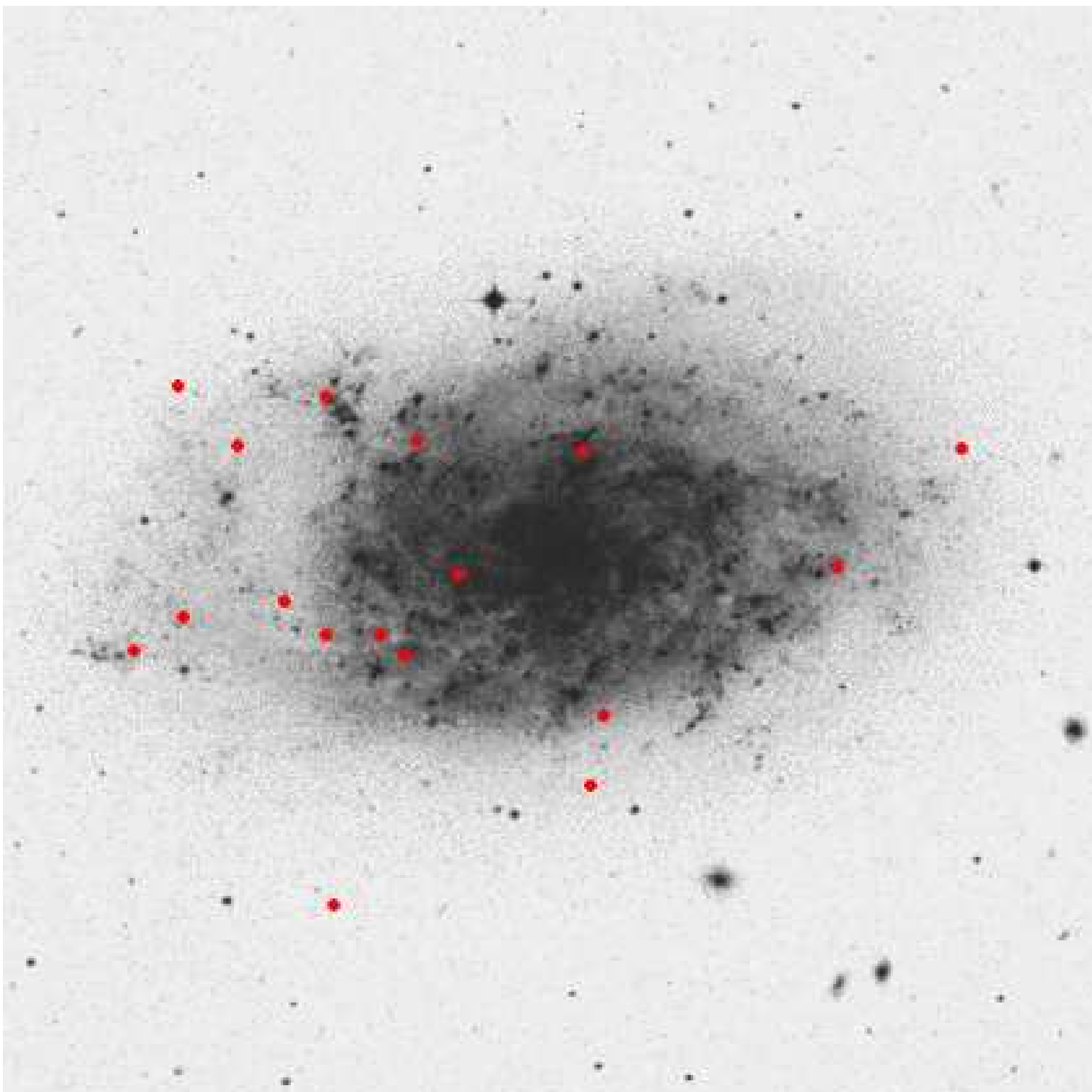

Fig. 1.— DSS map of NGC 7793, showing the positions of the discovered Cepheids. North is up, and east to the left. The field of view is about 12' x 12'

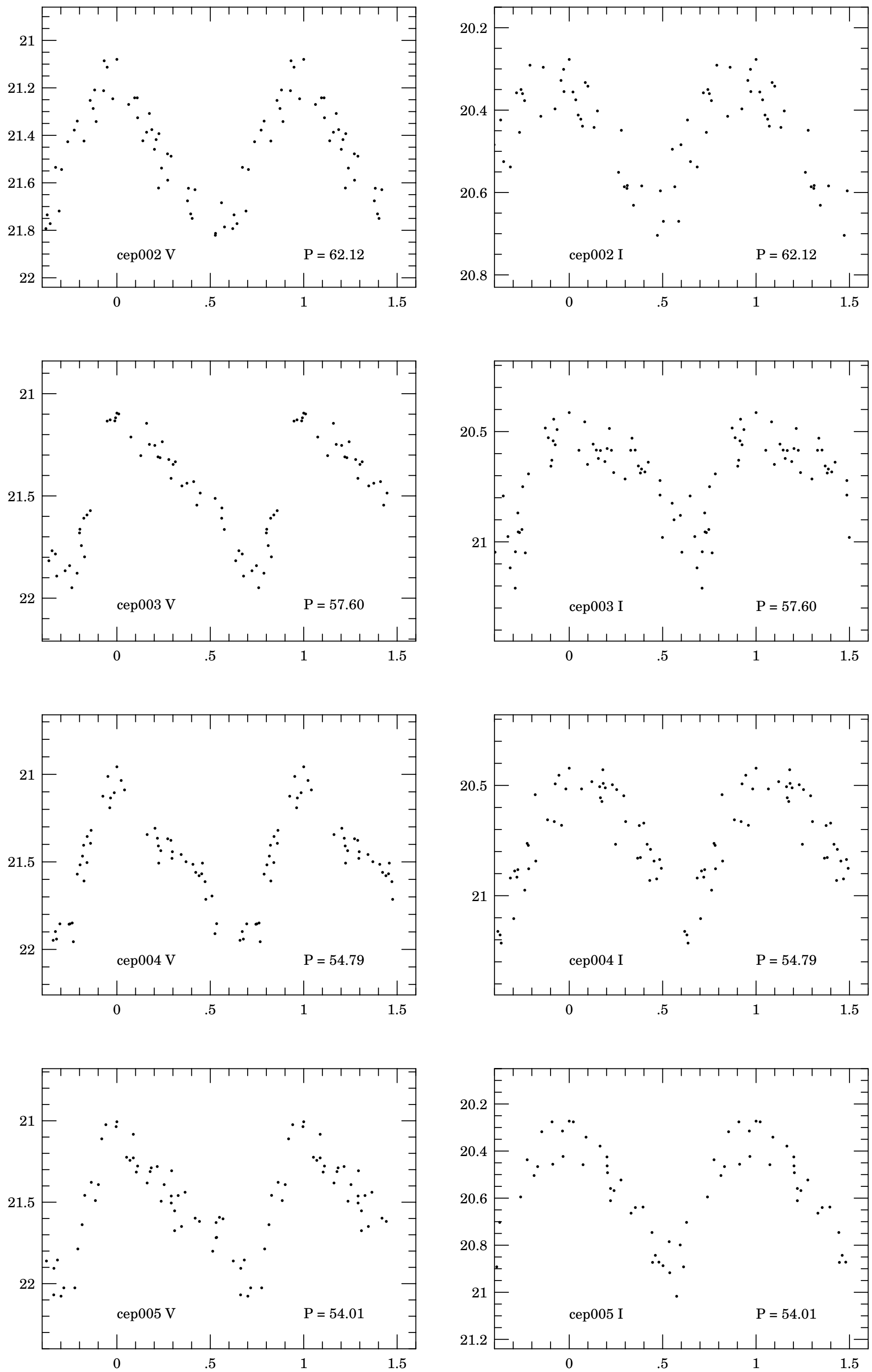

Fig. 2.— The V- and I-band light curves for the 17 NGC 7793 Cepheids discovered in our survey. Individual observations are listed in Table 1, and periods to phase the observations were taken from Table 2.

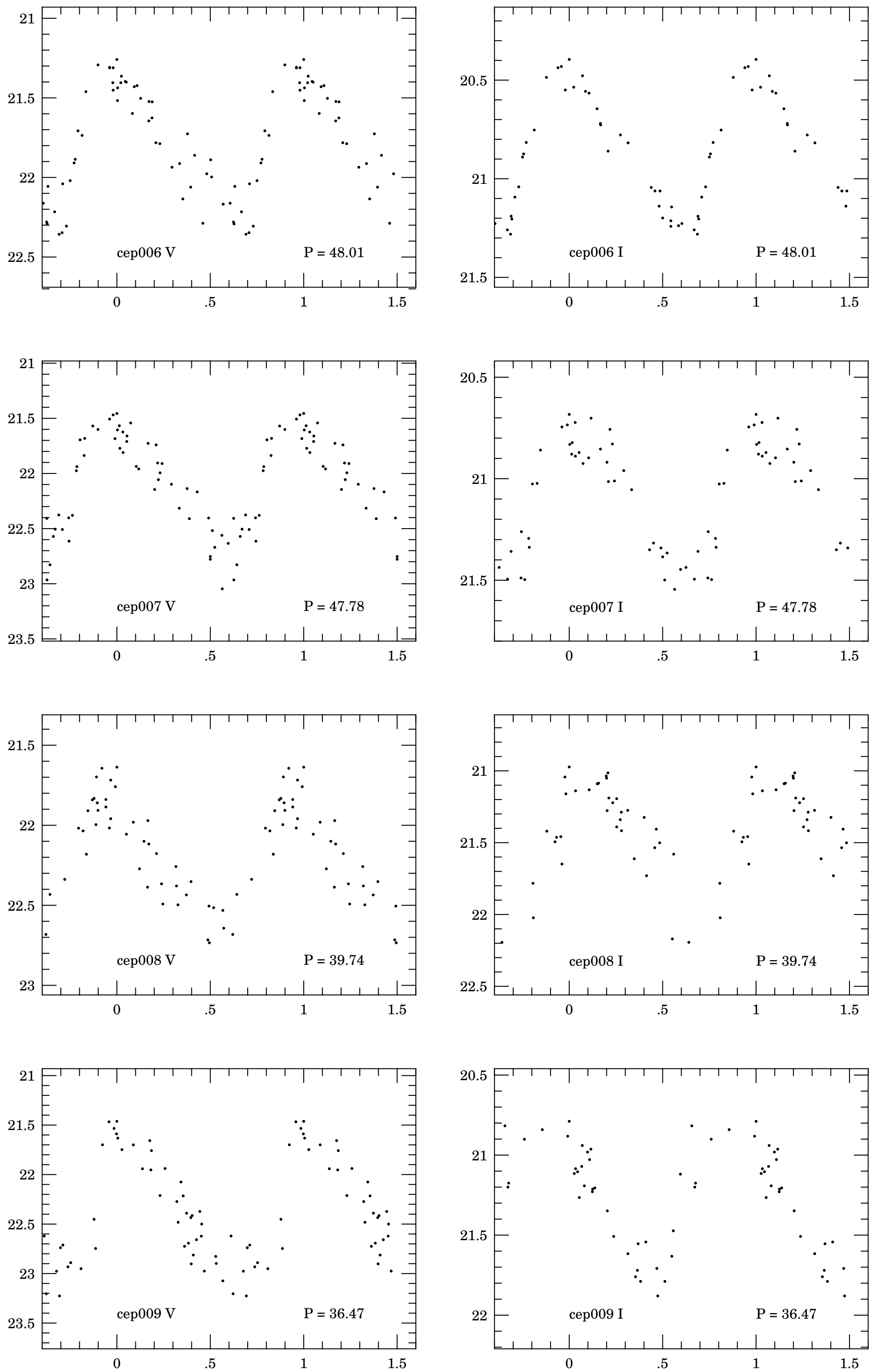

Fig. 2.— Continuation

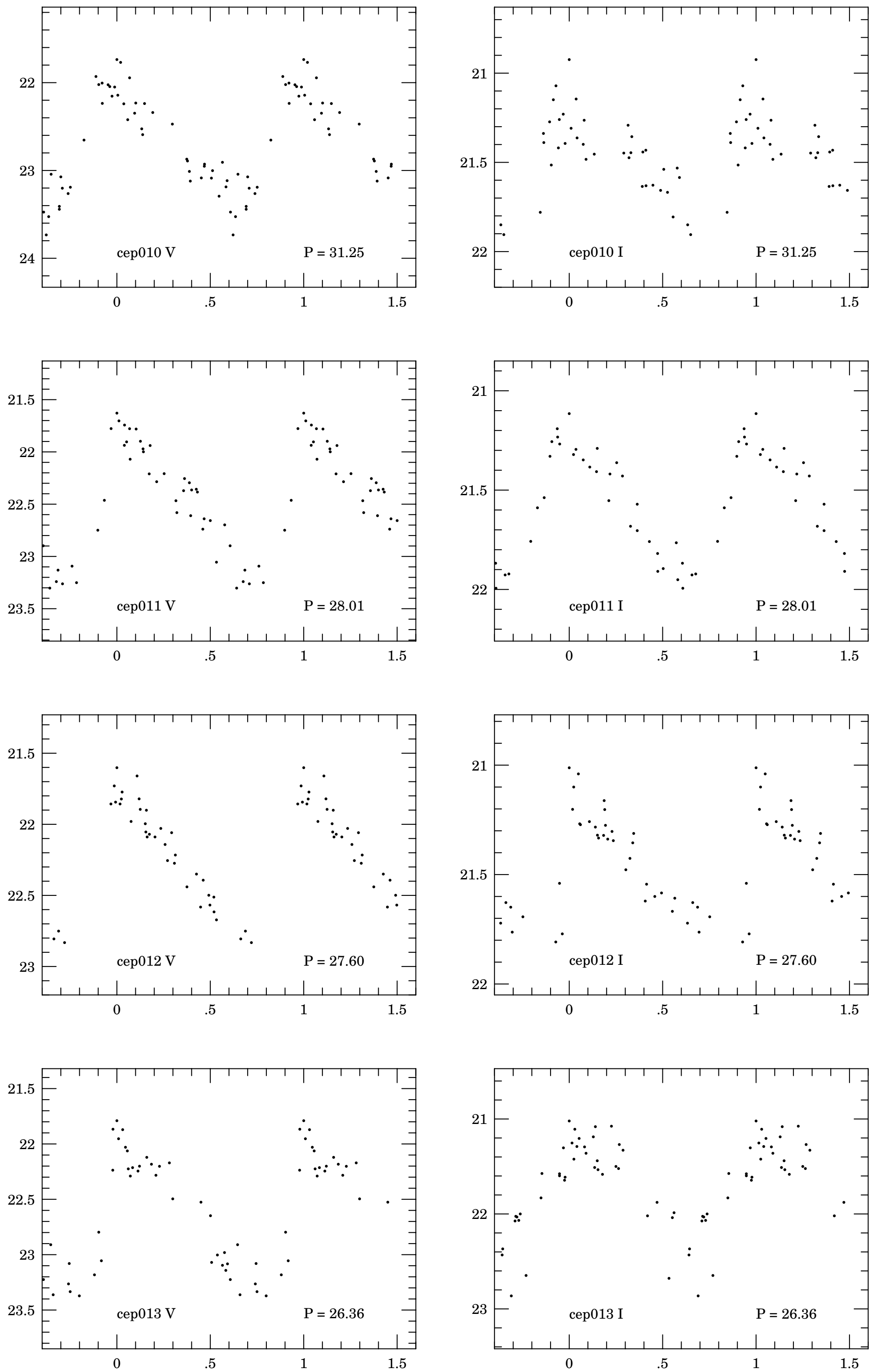

Fig. 2.— Continuation

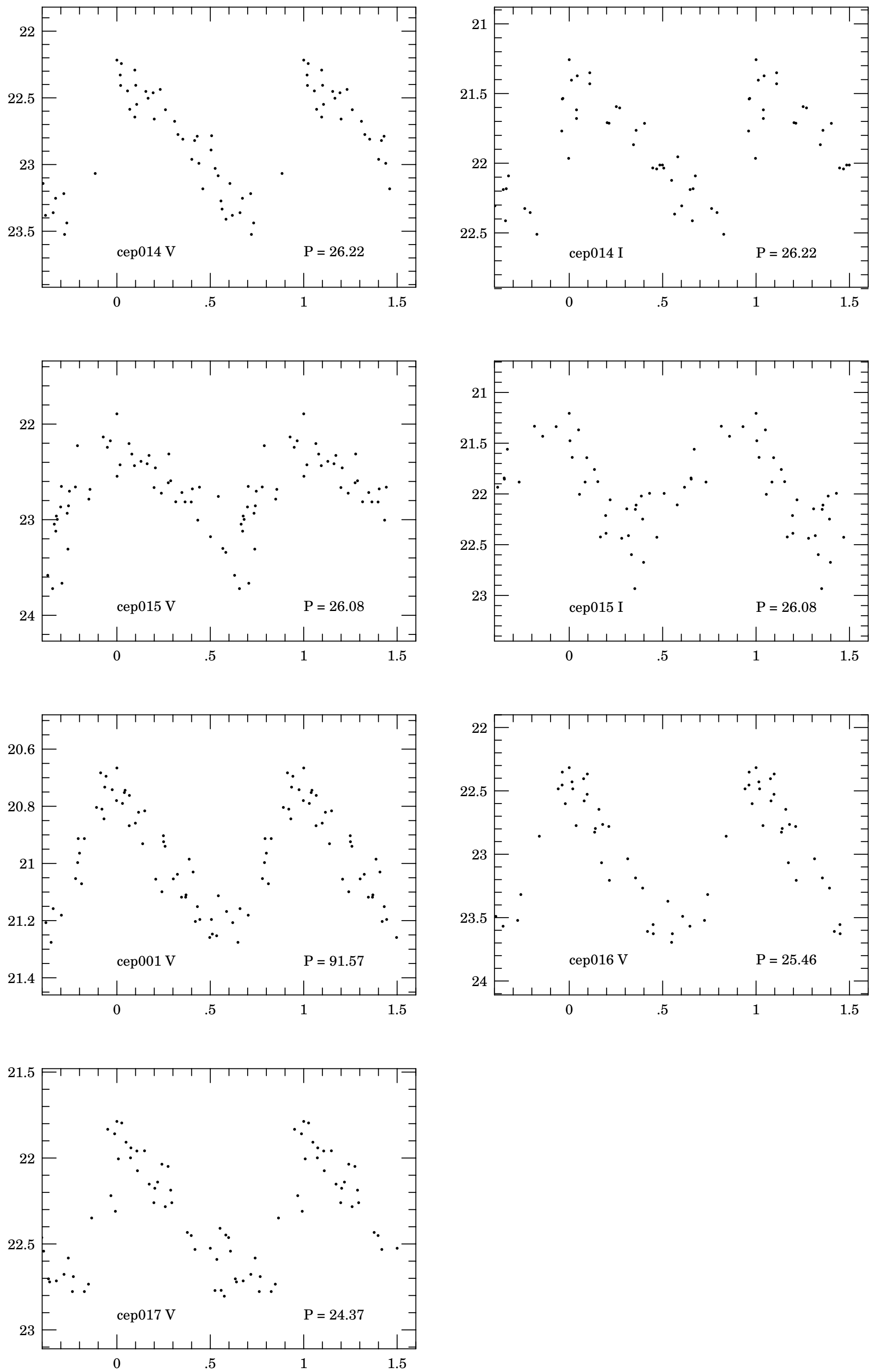

Fig. 2.— Concluded

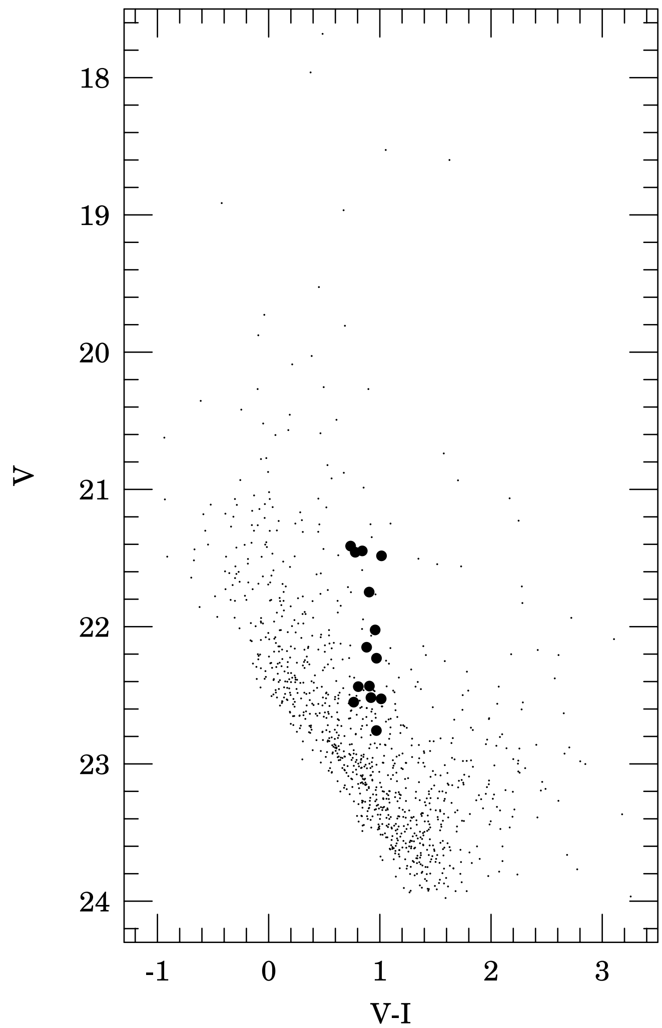

Fig. 3.— The V,V-I magnitude-color diagram for NGC 7793. The discovered Cepheids (filled circles) populate the expected instability strip for classical Cepheids in this diagram. It is seen that the faintest Cepheid in our sample is still about 1 mag brighter than the faintest stars in NGC 7793 detected and measured in our photometry, eliminating a Malmquist bias as a significant source of error in our distance determination.

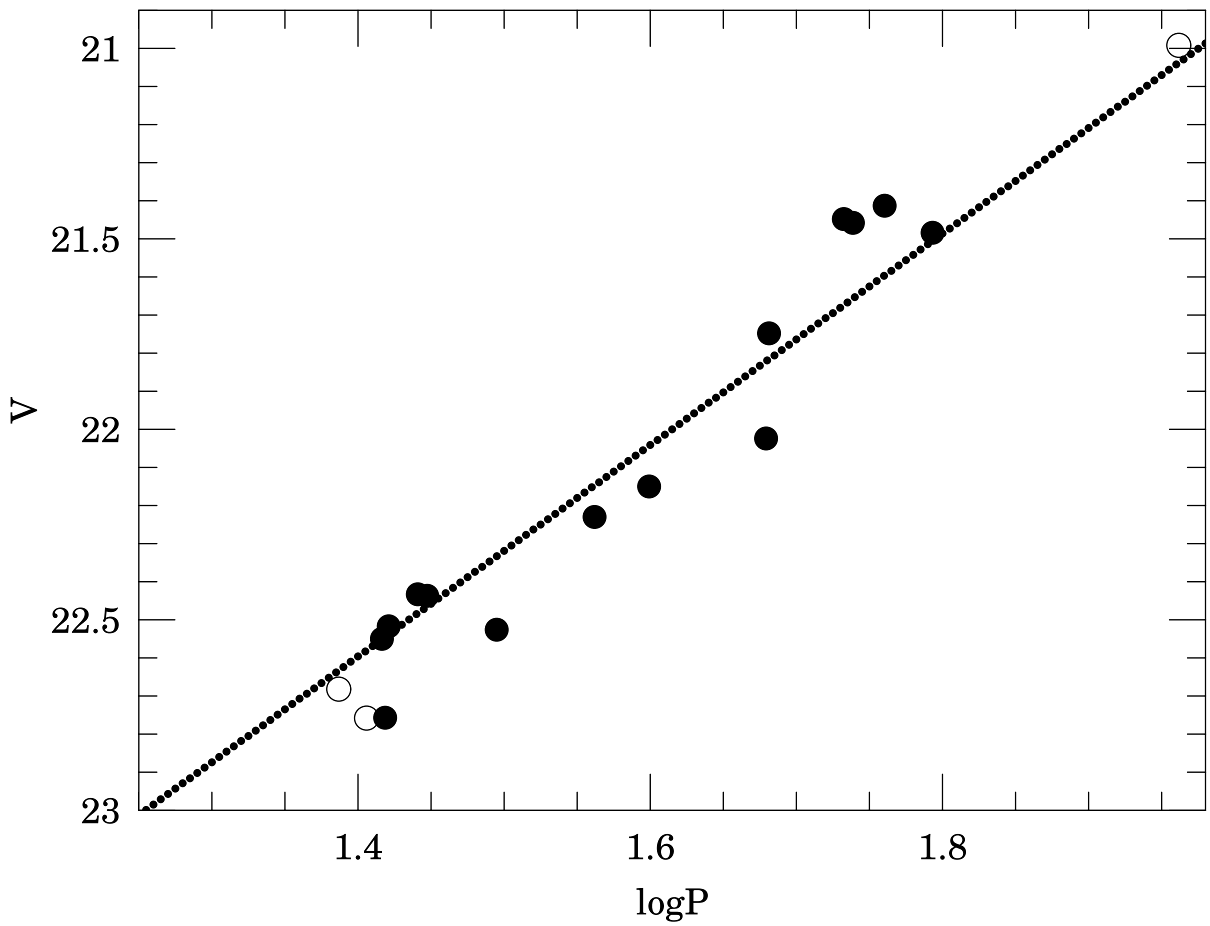

Fig. 4.— The period-luminosity relation for NGC 7793 Cepheids in the V band. The 14 Cepheids indicated with filled circles have both V and I mean magnitudes. The 3 Cepheids marked with open circles have only V-band data. The slope of the fitting line was adopted from the LMC Cepheids (OGLE II).

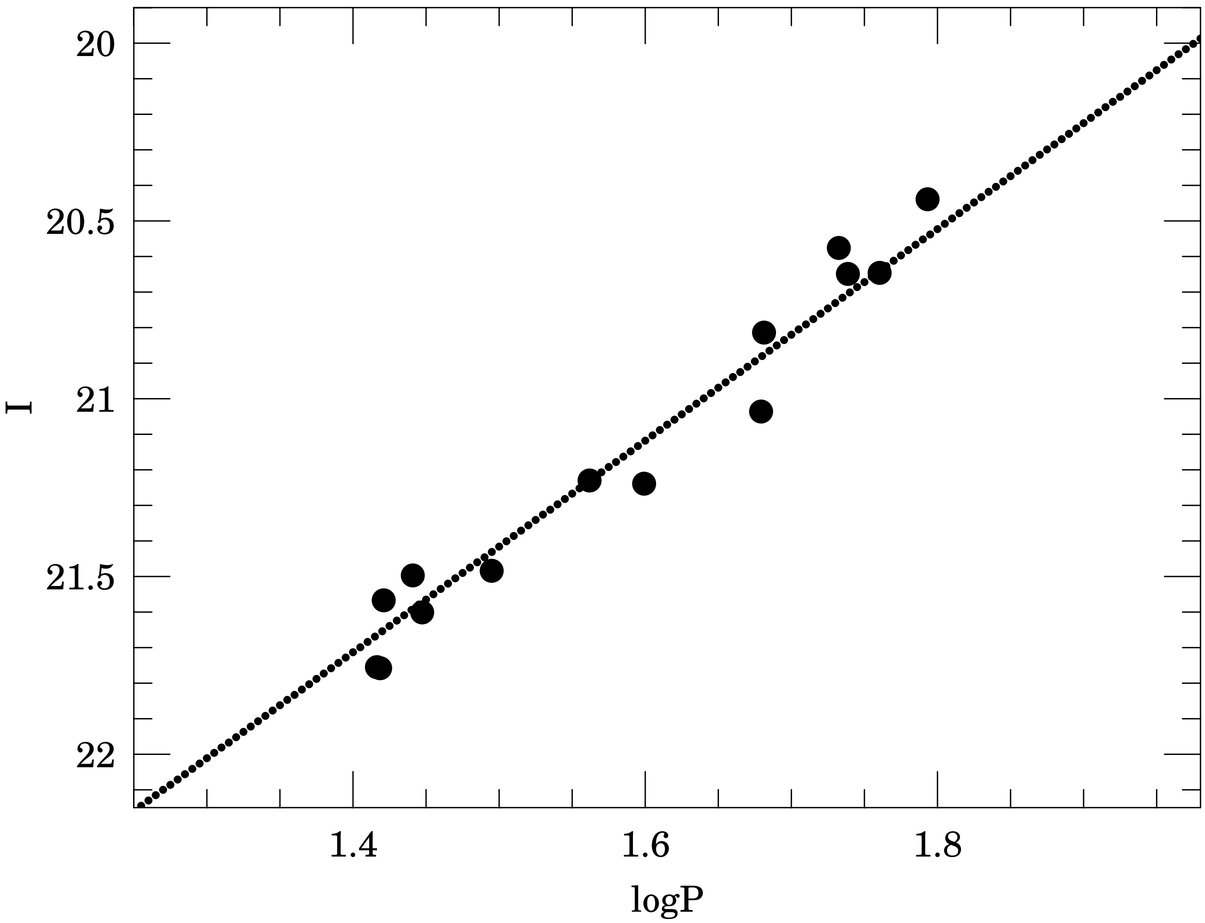

Fig. 5.— Same as Fig. 3, for the I band.

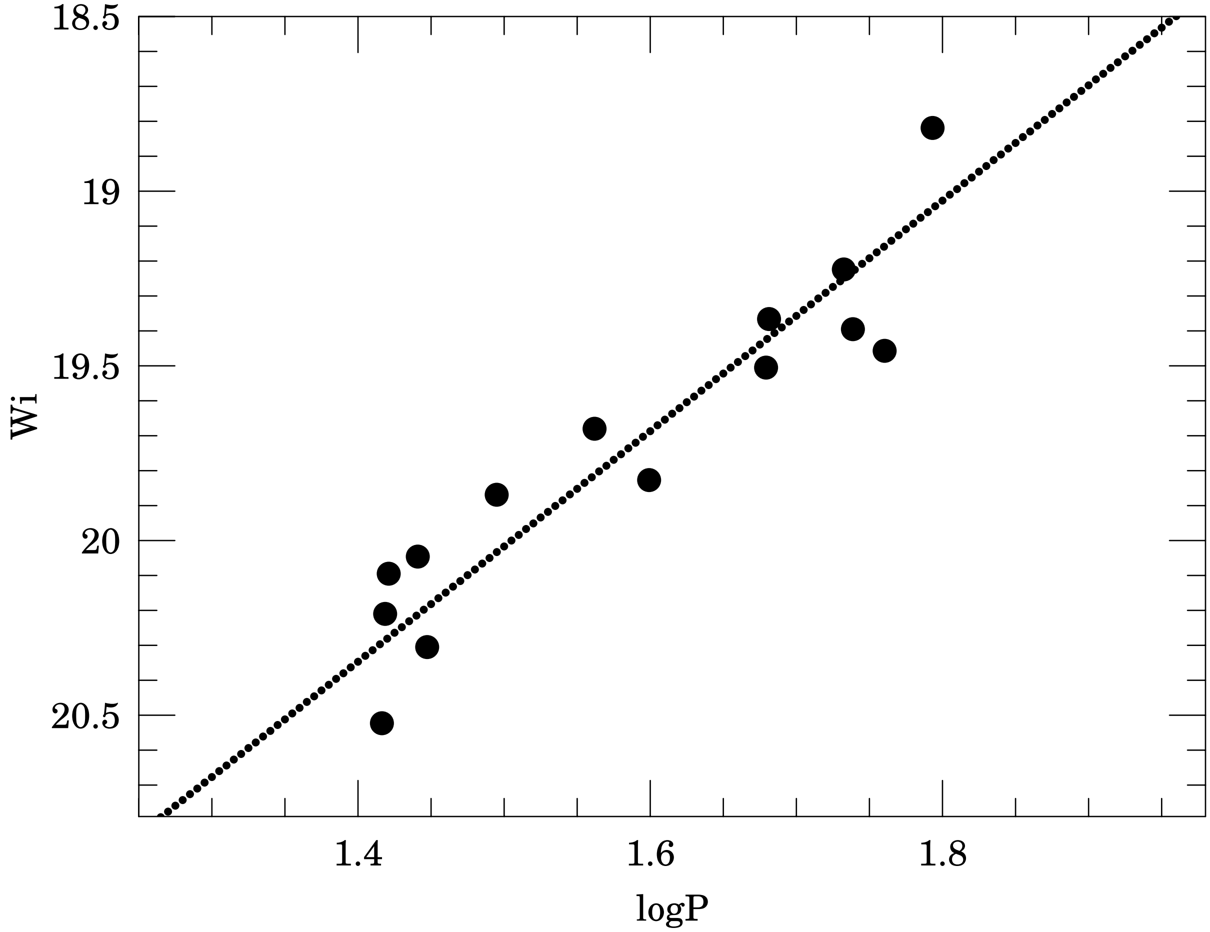

Fig. 6.— Same as Fig. 3, for the reddening-independent (V-I) Wesenheit magnitudes.